

Dear Reviewers #1

Thank you for the time and care you devoted to reviewing our manuscript for Systems (MDPI). We, the authors, have revised the paper thoroughly to address the comments provided by you. In the sections that follow, we respond to each comment point by point and describe the corresponding changes in the revised manuscript. For the reader's convenience, the Overview section summarizes the most substantive revisions and indicates where they have been incorporated. We believe the manuscript has improved substantially as a result of the review process.

Overview

This section summarizes the principal revisions made to the manuscript in response to the reviewers' comments. Each item below briefly states what was changed and why, to facilitate verification in the revised submission.

1. The abstract has been substantially rewritten to reflect the revised manuscript more accurately. It now states the paper's purpose and logic more explicitly, clarifies the comparative and qualitative nature of the study, and highlights the manuscript's main contribution and novelty.
2. Section 1, *Introduction*, has been extended and improved. The introduction has been extended to (i) better motivate the relevance of MBSE for emerging digital approaches to general aviation certification, (ii) incorporate additional references that broaden and update the supporting literature, and (iii) include a short guide to the manuscript's structure to help readers navigate the paper.
3. To respond to the reviewers' requests for clearer contextual framing, the manuscript has been expanded and now includes the following sections:
 - a. Section 2, *Certification landscape*, clarifies the certification framework relevant to general aviation aircraft within the manuscript's scope and explains the role of EASA Acceptable Means of Compliance 1 (AMC1), focusing on the applicable ASTM consensus standards used for substantiation.
 - b. Section 3, *Reference aircraft architecture*, introduces the reference aircraft (loosely based on the Tecnam P2012 Traveller) and documents the input dataset and representative outputs used to illustrate the maneuvering and gust flight envelope calculations. Key values are consolidated in tables for ease of consultation, and a figure provides a three-view representation of the reference configuration.
 - c. Section 4, *The digital certification workflow*, provides a high-level description of the proposed digital certification framework and explains the modeling principles used to encode regulatory content in SysML. It also describes the user-defined stereotypes employed to capture certification information and includes figures that summarize the workflow and the associated modeling constructs to improve readability.
4. Section 5, *Comparison of the two methodologies*, has been reorganized to improve coherence and readability. New figures have been added to represent the workflows more explicitly and to clarify the architecture and execution logic of each toolchain. In addition, the subsection describing the CATIA MSoSA implementation now includes a concise description of the supporting C++ code suite to make the computational backend easier to follow.
5. Section 6, *Results*, has been tightened to focus on the most relevant outputs for the manuscript's comparative aim. It now includes a code listing that illustrates the structure of the JSON file exported from the CATIA MSoSA environment and used to parameterize the C++ calculation routines.

6. Section 7, *Discussion*, provides an explicit qualitative comparison of the two MBSE toolchains. The comparison is presented both graphically (using a summary table and radar/spider charts) and textually through defined qualitative key performance indicators (KPIs) that guided the assessment. The section concludes with brief, integrative remarks that synthesize the main trade-offs identified in the comparison.

Answers to the Comments

The paper novelty needs to be clarified. Actually, the paper lacks new theory, new methodology, new algorithm, and framework definition and is implementing well established methods and concepts.

The authors appreciate this observation and apologize for the lack of clarity in the first draft of our article. The novelty of the article consists of the implementation and testing of digital facilities capable of storing the certification requirements, allowing the certification engineer to quickly retrieve and apply certification rules and enabling the automatic execution of certification calculations, generating certification artifacts necessary for showing compliance (substantiation/proof of compliance).

The digital facilities are now correctly illustrated, giving a thorough overview of the SysML stereotypes at the core of their development. The authors explored the concept of automatic certification for Subpart C, following accepted methodologies automatically parsed from substantiation documents issued by regulators and included in the aviation industry consensus standard. This is a novel approach to certification. Therefore, there was a need to explore more than one technique for implementing the framework. The comparison will be useful to other researchers as a source of information and lessons learned while attacking this ominous problem. The authors hope that the article now explains these aspects with enough clarity and thoroughness, as you rightly requested.

For your convenience, the authors will include citations from the manuscript where the novelty is now explicitly stated and clarified:

Paper quote—Abstract

This article evaluates two model-based systems engineering (MBSE) toolchains that support aircraft certification under EASA CS-23 Amendment 6.[...] Airworthiness requirements and associated acceptable means of compliance are digitalized as Systems Modeling Language (SysML) models that preserve document structure and encode parameters and expressions needed for substantiation.[...] The maneuvering and gust flight envelope required by CS-23 Subpart C is used as a representative case to compare workflow integration, robustness, and artifact generation.[...] Both toolchains generate certification-relevant outputs, including design airspeeds, limit load factors, and flight-envelope plots, while improving traceability relative to document-centric practice.[...] The comparison indicates that the Papyrus/MATLAB approach supports rapid prototyping but is more sensitive to regulatory text changes, whereas the MSoSA-based approach reduces dependence on text-pattern parsing and provides more integrated execution.

Paper quote—Section 1, Introduction

The methodologies discussed in this work aim to establish an MBSE toolchain that supports the integrated management of these documents, improving traceability and maintainability within a certification-item database.

[...]

The digital certification framework developed in this work uses SysML together with MATLAB/Simulink and C++ code suites and is demonstrated through two implementations: one based on Eclipse Papyrus and another using CATIA Magic Systems of Systems Architect (MSoSA).

Paper quote—Section 2, Certification Landscape

The two methodologies proposed in this work enable the user to apply relations such as Equation (1) automatically, ensuring that boundaries are enforced and checked against appropriate limits.

Paper quote—Section 3, Reference aircraft architecture

The main objective of this work is to evaluate and compare two different automated approaches for generating these certification artifacts...

Paper quote—Section 4, Digital certification workflow

Figure 3 presents the general conceptual design of the digital certification framework.

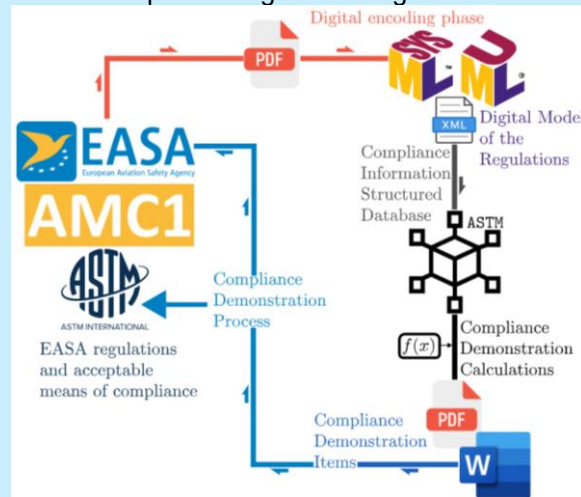


Figure 3. The digital certification framework and its general conceptual design.

Paper quote—Section 5, Comparison of the two methodologies

The primary objective was to establish and demonstrate a digital certification capability within the CATIA MSoSA environment, which this study achieves.

Paper quote—Section 8, Conclusions

The primary purpose of this study is to present two MBSE-based methodologies for developing a digital certification framework, thereby providing a reference for examining and comparing alternative approaches to this complex engineering process.

The authors hope that the changes applied are in close agreement with your kind suggestions, describing the novelty both visually and in the text content of the article.

In addition to the novelty, there is not quantitative evaluation. There is not comparison or metrics or KPIs to prove the reliability of the paper.

Thank you for your kind suggestion. The manuscript now includes Section 7, Discussion, with a description of a set of qualitative KPIs that helps the reader understand the underlying logic of the comparison presented by the study.

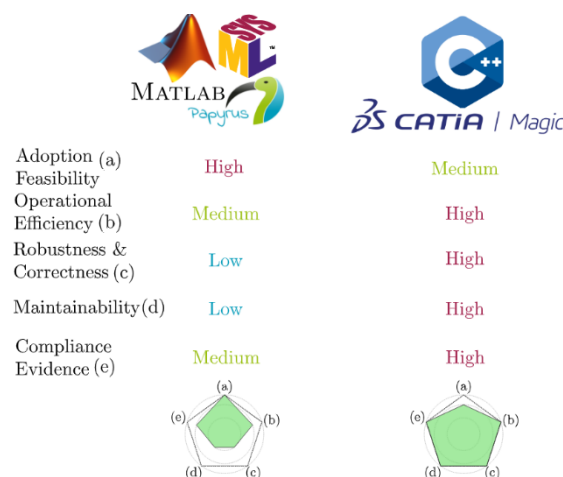


Figure 1 Quantitative KPIs.

Figure 1 presents the qualitative evaluation graphically. Although the comparison is only qualitative, the quantitative comparison will be the subject of further studies, focused on figures of merit that can help practitioners to establish the best course of action in adopting and deploying new digital approaches to the aviation certification process. The authors are engaged in the process of establishing an appropriate set of quantitative figures of merit through a combined approach: sensitivity studies will be conducted, executing the MBSE frameworks repeatedly with different certification scenarios (including non-standard aircraft architectures), while a series of surveys will be conducted in collaboration with industrial partners, without disclosing sensitive information. Unfortunately, this is a complex task, and the authors are still in the process of establishing which data can be included in a scientific paper.

The selected KPIs are the following:

- Adoption feasibility.
- Operational efficiency.
- Robustness and correctness.
- Maintainability.
- Compliance evidence.

For a thorough description of these KPIs, please refer to Section 7 of the revised manuscript. The authors hope that this qualitative evaluation and discussion will be satisfactory.

Most of the paper is descriptive and no analytic or experimental evaluation is provided.

Thank you for your comment. The authors compared two MBSE approaches for certification digitalization using a reference aircraft architecture loosely based on the Tecnam P2012 Traveller, a small commercial transport aircraft designed for brief commuting flights. The paper now includes a description of the reference architecture, with an overview of its geometrical and aerodynamic characteristics. Figure 2 reports the aircraft data table included in the revised manuscript.

Input data	Value
Maximum lift coefficient, $C_{L_{\max}}$	1.46
Minimum lift coefficient, $C_{L_{\min}}$	-0.80
Lift curve slope coefficient, $C_{L_{\alpha}}$	4.71 rad ⁻¹
Wing Loading (SI units), $\frac{W}{S}$	1352.79 kg m ⁻²
Wing Loading (Engineering units), $\frac{W}{S}$	28.25 lb ft ⁻²
Density at the reference altitude, ρ_{ref}	0.85 kg m ⁻³
Density at sea level, ρ_0	1.22 kg m ⁻³
Mean aerodynamic chord, MAC	1.82 m
Aircraft mass (Engineering units), M	8113.00 lb
Gust intensity at cruise speed, U_{dec}	15.24 m s ⁻¹
Gust intensity at dive speed, U_{dep}	7.62 m s ⁻¹
Gust intensity for rough air speed, U_{deb}	20.12 m s ⁻¹
Max. hor. airspeed at sea level, V_H	93.38 m s ⁻¹
Max. hor. airspeed at reference alt., V_H	104.65 m s ⁻¹
Reference altitude h_{ref}	12 000.00 ft
Max. cont. power (Eng. units) P_{MC}	375.00 hp × 2
Max. cont. power (SI units) P_{MC}	279.64 kW × 2

Figure 2 Aircraft data reference table.

Figure 3 presents another table included in the revised manuscript for illustrative purposes. The data shows a good agreement with a typical CS-23 evaluation of the maneuvering and gust flight envelope for the selected aircraft reference architecture. The authors performed no experimental evaluation of the data, mainly because the purpose of the manuscript was to compare two possible digital certification frameworks, both working with accepted and well-known methodologies directly parsed from the substantiation documentation. The most important part of the article is, therefore, the core MBSE mechanism underlying the two digital certification processes. This is now presented in Section 4, *The digital certification workflow*, where the design logic of the MBSE digital certification toolchain is presented. The authors hope that the revised manuscript now presents the links between the application of substantiation requirements and the aircraft data.

	PARAMETERS	h = Sea Level	h = 12000.00 ft
Airspeeds	Positive stall speed, $V_{S_{clean}}^+$	38.89 m s ⁻¹	46.72 m s ⁻¹
	Negative stall speed, $V_{S_{clean}}^-$	52.54 m s ⁻¹	63.11 m s ⁻¹
	Max. hor. design speed, V_H	93.38 m s ⁻¹	104.65 m s ⁻¹
	Design cruising speed, V_C	84.04 m s ⁻¹	89.00 m s ⁻¹
	Design maneuvering speed, V_A	71.98 m s ⁻¹	86.46 m s ⁻¹
	Negative design maneuvering speed, V_G	61.50 m s ⁻¹	73.87 m s ⁻¹
	Design dive speed, V_D	117.22 m s ⁻¹	124.14 m s ⁻¹
	Design rough air speed, V_B	84.04 m s ⁻¹	89.00 m s ⁻¹
Limit Load Factors	Stalling limit load factor, n_S	±1.00	±1.00
	Cruising limit load factor, n_C	3.43	3.43
	Maneuvering limit load factor, n_A	3.43	3.43
	Dive limit load factor, n_D	3.43	3.43
	Neg. maneuvering limit load factor, n_G	-1.37	-1.37
	Neg. cruising limit load factor, n_F	-1.37	-1.37
	Neg. dive limit load factor, n_E	3.43	3.43

Figure 3 Eclipse Papyrus/MATLAB calculated values for the maneuvering and gust flight envelope.

Is there any demonstrative or proof of concept of validation?

Thank you for your kind question. The scope of the article is intentionally methodological and comparative: we evaluate two MBSE toolchains for encoding AMC1 substantiation logic and for generating certification-relevant artifacts for EASA CS-23 Subpart C (Structure), using the maneuvering and gust flight envelope as a representative case.

With respect to “validation” in the certification sense, it is important to distinguish between (i) verifying that the toolchains correctly implement the published AMC1 procedures and produce the expected compliance artifacts, and (ii) validating the results against applicant–authority deliverables (e.g., proprietary substantiation reports, approved compliance checklists, and associated test evidence). The latter typically involves confidential datasets and regulated exchanges that cannot be disclosed publicly; accordingly, our manuscript adopts a representative, reproducible reference case and reports the generated artifacts in sufficient detail for readers to assess plausibility and repeatability within the stated scope. Finally, as noted in the manuscript, broader validation in operational or industrial settings (including quantitative KPIs and extended coverage beyond Subpart C) is planned as future work.

As a demonstrator, the paper executes the end-to-end workflow on a reference aircraft dataset and reports the resulting certification artifacts and intermediate quantities (e.g., design airspeeds and limit load factors) that are expected outputs when applying the accepted substantiation procedures. The demonstration is implemented twice—via two independent toolchains, Eclipse Papyrus/MATLAB and CATIA MSoSA/C++—and both implementations generate consistent outputs (tables and flight envelope plots), with close agreement in the reported numerical results despite minor differences in input assumptions and computational strategies. This cross-implementation consistency serves as an internal verification check aligned with the manuscript’s purpose: to compare workflow integration, robustness, and artifact generation across two MBSE approaches.

Large part of the paper describes the tools and seems to be like a project report or a technical documentation rather than a scientific paper.

Thank you for this observation. We agree that parts of the manuscript necessarily describe the two toolchains in sufficient detail to make the proposed workflows reproducible; however, the intent of the article is not to serve as technical documentation, but to present and compare two MBSE-based certification approaches using a qualitative evaluation framework. The technical content of the article is mainly encoded in the MBSE underlying infrastructure. The stereotypes and the workflow are now thoroughly described, providing the reader with a clear representation of our novel digital approach towards certification. The generality of the approach, in the context of general aviation architectures, is now clearly described with additional examples.

First, the manuscript is structured around a research objective and a comparative question, stated in the Abstract and Introduction, namely the evaluation of two MBSE toolchains for CS-23 Amendment 6 and their comparison in terms of workflow integration, robustness, and artifact generation (Abstract; Section 1). The study then formalizes a general digital certification workflow (Section 4) that is tool-agnostic at the conceptual level, and applies it to two implementations (Sections 5.1 and 5.2).

Second, the article includes demonstrative results rather than only tool descriptions. Tables 2 and 3 report computed airspeeds and limit load factors, and Section 6 presents certification artifacts (e.g., flight-envelope

plots) generated by both toolchains. The CATIA-based implementation additionally demonstrates structured export of regulatory parameters and expressions to JSON files to drive substantiation routines (Section 6.2) written in C++.

Third, the comparative contribution is made explicit through a defined set of qualitative key performance indicators (KPIs) in Section 7 (refer to the previous comment for a more thorough description). These KPIs provide the qualitative basis for comparing the two approaches and for discussing adoption trade-offs and limitations from a broad perspective, which are summarized in the Discussion and Conclusions.

The authors hope that the manuscript is now in keeping with your expectations and believe that it can serve as an interesting reference for implementing a digital certification toolchain using different approaches and strategies.

There is no formal MBSE framework, no uncertainty or sensitivity analysis.

Thank you for your observation. The MBSE framework is now fully described, giving the reader a clear picture of its structure. First, Section 4, *The digital certification workflow*, presents a tool-agnostic description of the concept of a digital certification framework, as imagined by the authors. This Section also presents an illustrative example of a Profile Diagram, defining a custom ASTM stereotype. Section 5, *Comparison of the two methodologies*, illustrates in two distinct Subsections the two possible applications of the conceptual structure previously presented, with different tools and encoding strategies. The authors emphasize the equivalence of the final outcomes and present a set of selected results in Section 6, *Results*. This Section includes two separate Subsections, conveniently separating the two methodologies.

The authors apologize for the lack of a sensitivity analysis. As already mentioned in a previous answer to your kind comments, the authors are still in the process of gathering the data for a subsequent scientific article that will include a more quantitative evaluation of the digital certification framework and an evaluation of its behavior under special circumstances, aircraft architectures, and other Amendments.

Regarding the application of MBSE in aerial vehicle design, you may take a look at the following paper; A unified and experimentally validated design framework for long-endurance solar UAVS using model-based multi-objective multidisciplinary optimization.

Thank you for referencing this interesting paper. The authors considered this comment very seriously and examined this reference with a high degree of thoroughness.

After consideration, however, we have not included it as a reference in the revised manuscript because it addresses a substantially different problem than the one examined here. The suggested study focuses on an end-to-end aircraft design and optimization workflow (including subsystem modeling, MDO integration, and experimental validation), whereas our manuscript is deliberately limited to a certification-oriented MBSE use case: the SysML-based digitalization of CS-23/AMC1 substantiation logic and the comparative assessment of two toolchains for generating a specific certification artifact (the maneuvering and gust flight envelope). Citing a comprehensive design-and-optimization framework in this context could inadvertently shift the framing of our contribution from certification evidence generation toward conceptual design methodology, which is not the goal of the present paper.

We nevertheless appreciate the suggestion, remaining open to further comments and suggestions for expanding and improving the bibliography, and view this line of research as complementary. The authors hope that the included references align with the revised manuscript scope.

The result section can benefit a validation or comparison against a reference solution of numerical assessment ...

Thank you for your kind suggestion. The revised manuscript now stresses the concept and logic of the substantiation process, addressing EASA CS-23, Subpart C. The authors have strengthened the manuscript by (i) reporting the key numerical outputs for the reference aircraft directly in Section 3, *Reference aircraft architecture*, and (ii) presenting the corresponding outputs produced by both toolchains (Eclipse Papyrus/MATLAB and CATIA MSoSA/C++) in a comparable form (Tables 2–3 and the associated flight envelope artifacts). The agreement between two independently implemented workflows serves as an internal verification comparison for the numerical assessment within the scope of this study, which is comparative and methodology-oriented.

A direct comparison against industrial certification reports would indeed provide an external reference; however, such reports are typically proprietary and cannot be disclosed. For this reason, we adopt a reproducible reference case, provide the complete input dataset used for the demonstrator, and document intermediate and final outputs that can be checked against the published AMC equations and regulatory bounds. We have also clarified this distinction between internal verification and external/industrial validation in the revised manuscript and note that broader industrial validation (when disclosure is permitted) is planned as future work.

To further support reproducibility without increasing manuscript length substantially, we can include an Appendix summarizing the reference input dataset and a compact checklist of verification steps (e.g., enforcement of regulatory bounds and consistency checks) used during execution. The authors remain open to your kind suggestions and guidance for improving the clarity and readability of the final manuscript.

Final Comments

Thank you for your careful reading of our manuscript and for the constructive feedback provided throughout the review process.

The authors have addressed each comment in detail and revised the manuscript substantially to improve its clarity, completeness, and presentation. In particular, we strengthened the contextual framing and motivation, clarified the scope and contribution, and expanded the manuscript structure to make the workflow and comparative objectives easier to follow.

As reflected in our point-by-point responses, the revised manuscript now provides a more explicit description of the certification landscape and of the digital certification workflow, and it reports demonstrative results for the representative case—the maneuvering and gust flight envelope—used to compare the two MBSE toolchains. We also clarified the role of each software environment and the nature of the generated certification artifacts, while maintaining the manuscript's intentionally methodological and comparative focus. We are grateful for the reviewers' suggestions, which materially improved both the technical exposition and the readability of the paper. We hope that the revisions satisfactorily address the concerns raised and that the manuscript is now suitable for publication in Systems (MDPI). We remain at the editors' and reviewers' disposal should further clarifications or refinements be required.

**Sincerely,
The Authors**

Claudio Mirabella

Ph. D. Student, University of Naples, Federico II

Michele Tuccillo

Ph. D. Student, University of Naples, Federico II

Pierluigi Della Vecchia

Associate Professor of Flight Mechanics, University of Naples, Federico II